3.3 GEOLOGY AND SOILS

This section describes soils and geologic conditions on and affecting the project site, and assesses the geologic and soils impacts, constraints, and hazards on the Emerson, Burroughs, and Gilbert parcels, as well as the Ironhouse parcel. Geologic and soils issues addressed herein include seismic (earthquake) hazards, slope stability, soil expansion, settlement, and erosion. This analysis is based on a review of soils and geologic studies and maps prepared by private consultants and resource agencies for the region, project site, and adjacent development projects.

3.3.1. Affected Environment

Regional Geology

The Dutch Slough Restoration Project and Related Project sites are located in the Great Valley Geomorphic province, near the eastern boundary of the Coastal Range province. These two provinces display different topography, geology, climate, and faulting. The Great Valley is an alluvial plain approximately 50 miles wide, extending 400 miles through the middle of California. Approximately 3 – 6 miles of sedimentary deposits underlying the valley accumulated in the former marine setting over the past 160 million years (Atwater 1982). The confluence of California's two principal rivers, the Sacramento and San Joaquin, is immediately west of the Site. Glacial outwash and weathered material from the Sierra Nevada mountain range is the source of historic sediments and parent material transported from the numerous major drainages of the Sierra into the Sacramento and San Joaquin rivers. Several hundred feet of unconsolidated to weakly consolidated material accumulated in the Dutch Slough site vicinity over the thousands of years of fluctuating sediment deposition and erosion. Hydraulic mining debris generated during the gold rush in the mid-1850s significantly altered natural deposition processes in the Delta as hundreds of thousands of tons of silt washed down from the Sierra Nevada altering stream channels and sloughs and raising natural levees. The adjacent San Francisco Bay, located in the Coastal Range geomorphic province, is a subsided basin marked with active north-west trending fault lines. This seismically active region includes numerous faults. Proximate faults include the Greenville, the Concord-Green Valley, and the Mt. Diablo Thrust, as well as major regional faults including the Hayward, San Andreas, Concord, and Calaveras.

The regional geomorphology is dominated by the confluence of the Sacramento and San Joaquin rivers and an interconnected assemblage of sloughs and islands. Artificial levees ring the perimeter of these islands, which are largely below sea level exhibiting varying extents of subsidence.

Project Area Geologic Units

The USGS Geologic Map and Map Database of Northeastern San Francisco Bay Region identify the following major geologic units at the Dutch Slough Site or in the immediate vicinity (Graymer, Jones, and Brabb 2002). For reference, the time periods for the geologic epochs identified include the Holocene (8,000 years ago - Present) and the Pleistocene (1.8 million - 8,000 years ago).

> **Qhb:** Basin deposits (Holocene) – Very fine silty clay to clay deposits occupying flat-floored basins and flat areas. Basin deposits bury older eroded sand dunes.

Qds: Dune sands (early Holocene and latest Pleistocene) – Very well sorted fine- to medium-grained eolian (wind-blown earth material) sand. These sands were historically deposited during periods of lower sea levels, prior to present day levels.

Qhdm: Delta mud deposits (Holocene) – Predominantly mud and peat with lesser silt and sand deposited near seal level in the Sacramento-San Joaquin Delta. Much of this unit was diked, dried and farmed and is currently compacted and deflated.

Ac: Artificial channel deposits (Historic) – Common to modified stream channels, such as Marsh Creek, realigned and concrete lined or barriered for flood control.

Alf: Artificial levee fill (Historic) – Various materials used to create levees in the Delta over the past 150 years. Materials, ages, and integrity vary, most constructed prior to 1965 are simply uncompacted, dumped materials.

Site Soils

The Dutch Slough vicinity is underlain by the Upper Modesto Formation consisting of alluvial sand deposited over thousands of years. Initially derived from the Sierra Nevada mountain range, these outwash deposits sands were locally redistributed by winds to form dunes. Previous geologic investigations in the vicinity indicate these unconsolidated eolian (wind- deposited) deposits of sand are ~10,000 to 40,000 years old (Kleinfelder 2006; PWA 2006). Delta peat and organic soils formed as sea level rise began at the end of the last ice age roughly 11,000 years before present. The sand layer extends to depths of 50 ft below mean sea level (NGVD), with irregular layers of alluvial silt and clays and sands extending deeper. Sand surface elevations ranging from -16 to +2 ft NGVD (PWA 2006).

Natural Resources Conservation Service (NRCS) Soil Survey map indicates 11 soil series present at the site (SCS 1977). These soils include Delhi Sand, Piper Sandy Loam, Ryde Silt Loam, Sycamore Silty Clay Loam, Egbert Mucky Clay Loam, Capay Clay, Marcuse Clay, Sacramento Clay, Kingile Muck, Rindege Muck, and Shima Muck (SCS 1977). These soils reflect different sources including local parent material, alluvial deposits, and imported soils and therefore represent a rather wide range of textures and properties.

Typically a site's parent material affects soil composition and thus exhibits influence over the plant community structure and distribution. This in not the case at Dutch Slough because disturbance and previous land uses including agriculture and sand mining altered the landscape. The soil and vegetation at Dutch Slough were removed, amended, and generally modified over time with changing land uses (PWA 2006). Prior to levee construction and land reclamation around the turn of the century, ground surface elevations are estimated to be 2 ft NGVD. However, as groundwater levels were lowered for farming and ranching, oxidation of the surface peat material and subsequent subsidence lowered ground surface elevations.

The northern portions of the site are principally fine grained muck soils, which reflect the historically very poorly drained organic soils that formed from the decomposition of reeds and tules and the accumulation of alluvial deposits over thousands of years. A patchwork of silty loams and clays extend across the majority of the four parcels, with a notable band of sand on the Emerson Parcel and a smaller patch on the Gilbert Parcel. The sand (Dehli) is characteristic of the historic Antioch dunes complex (PWA 2006). The Ironhouse parcel contains similar soils as the Emerson Parcel, which includes Marcuse clay, Capay clay, Dehli sand, and Sycamore silty clay loam (SCS 1977).

Local and Regional Seismicity

The seismically active San Francisco Bay region includes the San Andreas and other significant regional faults including the Hayward, Concord, and Calaveras. Additionally, Dutch Slough is in the vicinity of the Greenville, the Concord-Green Valley, and the Mt. Diablo faults. The San Andreas is the major fault system. This right-lateral strike slip fault indicates the tectonic boundary between the Pacific Plate to the west and the North American plate to the east. Over the last 160 years, it has produced numerous small-magnitude and a dozen moderate- to large-magnitude earthquakes (magnitude >6) in the Bay Area, including the 1906 San Francisco (M8+), the 1838 and 1865 San Francisco quakes (M7), and the 1989 Loma Prieta (1989). Recent activity on nearby faults includes the Calaveras faults' 1861 San Ramon Valley (M5.7) earthquake, the Greenville faults' Livermore (M5.4), the 1889 Antioch (M6.3), the 1955 Concord (M5.4), and the 1868 Hayward (M6.8) quake.

A 2003 report by the U.S. Geological Survey (USGS) indicates that there is a 62% probability of at least one magnitude 6.7 or greater quake in the greater San Francisco Bay area between 2003-2032 (USGS 2003). An earthquake of this magnitude is likely to result in widespread damage in portions of the greater Bay Area. The Earthquake Probability Map indicates the probability for each major fault (USGS 2003). The report concludes the probabilities of a >6.7M earthquake on the faults proximate to Dutch Slough are lower (Greenville 3%, the Concord-Green Valley 4%, and the Mt. Diablo Thrust 3%) than other major regional faults. The Coast Range-Central Valley (CRCV) or Great Valley fault geomorphic block is a blind thrust fault (below ground surface) known to have caused earthquakes at depth but has not caused surface ruptures in the recent geologic history. This indicates the site is potentially subject to significant ground shaking resulting from a quake occurring along any of the major regional faults. Due to the site's proximity to the Greenville Fault, located approximately 9 miles away, the site is identified by the CBC as located in Seismic Zone 4 and therefore subject to more stringent earthquake-resistant design standards.

Several previous studies of seismicity have been conducted for projects in close proximity to the Dutch Slough site. A May 2006 study by Kleinfelder included a seismic source characterization of the East Cypress Corridor (Kleinfelder 2006). The study discusses alternative models of source characterization and presents a summary of seismic parameters based upon the California Geological Survey (CGS 1996) Coast Range-Central Valley (CRCV) model. Table 3.3-1 identifies the seismic source parameters for significant regional faults as presented in the Jersey Island Road Levee Evaluation (Kleinfelder 2006).

Surface Fault Rupture

Typically, surface ruptures are confined to a narrow linear band typically located within feet (typically < 10 – 20 feet) of the fault line but potentially occurring short-distances (< 250 feet) of the fault line. The California Geological Survey (CGS) does not identify any Fault Hazard Zones or known active faults on the Dutch Slough site or in the immediate vicinity (CA Department of Conservation, Division of Mines and Geology 1999).

Ground Shaking

Significant ground shaking is likely to occur at the Dutch Slough site in a major earthquake. There is a 3% probability that one or more earthquakes with a moment magnitude > 6.7 will occur along the Greenville fault prior to 2031 (Working Group on California Earthquake Probabilities 2003). The

Table 3.3-1. Seismic source parameters for significant regional faults as presented in the Jersey Island Road Levee Evaluation (Kleinfelder 2006)

Fault Name	Fault Length (mi)	Closest Distance to Site (mi)	Magnitude of Maximum Earthquake**	Slip Rate (mm/yr)	Values of*	
					a	b
CRCV (Segment 6)	28	4	6.7	1.5	4.41	1.20
Clayton-Marsh Creek-Greenville	35	13	6.9	2	3.27	0.80
Concord-Green Valley	16	21	6.9	6	3.45	0.80
Calaveras (northern)	32	23	6.8	6	3.95	0.90
Calaveras (southern)	62	33	6.2	15	3.2	0.70
Hayward	50	33	7.1	9	3.49	0.90
West Napa	19	36	6.8	1	2.55	0.70
Rodgers Creek	37	45	7.0	9	3.96	0.90
San Andreas (1906 event)	292	51	7.9	24	1.37	0.70

* Parameters based on data presented by Real et al. (1978), Toppozada et al. (1978), Hart et al. (1984), Wesneousky (1986), Wong et al. (1988), Working Group of California Earthquake probabilities (1990), Wagner (1990), Schwartz (1994), Jennings (1994), Mualchin (1995), Frankel et al. (1996), and Petersen et al. (1996).

** Moment magnitude

severity of shaking is dependent upon many factors including the magnitude of the earthquake, distance from epicenter, duration of earthquake, and soil and geology. Unconsolidated sediments are prone to strong shaking and known to amplify and prolong ground shaking. Ground shaking is classified by the modified Mercalli intensity (MMI) which ranges from I (not felt) to XII (damage total, results in widespread devastation). Previous studies indicate a generalized MMI of VII (defined as strong) for Dutch Slough in a large magnitude earthquake (ABAG 2006; USGS 2006). MMI relates ground shaking to potential damage. MMI VII is described as resulting in negligible damage in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures, capable of generating waves on ponds; water turbid with mud. Small slides and caving in along sand or gravel banks, and damaging concrete irrigation ditches (ABAG 2006; USGS 2006).

Liquefaction

Soil liquefaction is the sudden loss of soil strength due to strong ground shaking typically associated with earthquakes. Liquefaction occurs when granular material is transformed into a fluid-like state due to increased pore-water pressure displacing granular soils and groundwater. Soil properties (soil type, grain size distribution), magnitude and duration of earthquake, and depth to groundwater are factors determining susceptibility to liquefaction. Sand and peat soils are more prone to liquefaction, whereas clay and silt are typically more stable soils. Unconsolidated materials have a high propensity for liquefaction. According to ABAG's Regional Liquefaction Map, the Dutch Slough parcels are identified as having moderate to high liquefaction potential (ABAG 2006).

Ground Lurching

Ground lurching occurs during earthquakes as a result of the rolling motion transferred to the ground surface leading to the formation of cracks in the surface. The potential for the formation of cracks is greatest between layers of material with different properties. The hazard of ground lurching at the Dutch Slough site is characterized as typical of other project locations in and around the San Joaquin Valley.

Landslides

The potential for landslide hazards at the Dutch Slough site is low because the site is relatively flat and not adjacent to any steep slopes. Existing levees have not experienced substantial landslides.

Lateral Spreading

Lateral spreading refers to the sliding or downward shifting of a top or overlying layer of soil generally due to liquefaction of the underlying soil layer. Typical zones of lateral spreading occur on slope faces or areas of incision. Previous studies indicate that the potential for lateral spreading in the vicinity is low and with maximum lateral movement likely to be less than one foot (Kleinfelder 2004). The greatest potential for lateral spreading is likely to be on unimproved levees proximate to sloughs and the existing canal (Kleinfelder 2004).

Levee Seepage

Levees are prone to through-seepage and under-seepage, which can lead to levee failure (DWR 2005). Through-seepage occurs in levees containing portions of relatively porous material that when subjected to prolonged periods of inundation (e.g., high water flood events) provide pathways conducive to flow through levees. Under-seepage occurs beneath levees underlain by porous soils, such as sand, allowing flow underneath a levee to the surface on the landward side. If left uncontained, such flow may result pressure in on the landward side of levees leading to ruptures in the surface soils commonly referred to as boils, as the typically circular shaped failures are reminiscent of the bubbling effect of boiling water. These conduits of flow result in levee slumping and eventual overtopping and failure. Under-seepage of site levees is reasonably probable as the local levees are underlain by sandy soils (Hultgren-Tillis 2006).

Regulatory Framework

State and local regulations that guide building and construction activities include several acts specifically regulating these activities in geologic hazard areas. In the seismically active San Francisco-Bay Delta estuary, these regulations are particularly relevant and applicable. The following section provides an overview of the principal regulations.

CALFED Delta Risk Management Strategy

A major need for the State is to determine how to make the Delta sustainable in the future. The 2000 CALFED Record of Decision presented its Preferred Program Alternative that described actions, studies, and conditional decisions to help fix the Delta. Included in the Preferred Program Alternative for Stage 1 implementation was the completion of a Delta Risk Management Strategy (DRMS) that would look at sustainability of the Delta, and that would assess major risks to the Delta resources from floods, seepage, subsidence, and earthquakes. DRMS would also evaluate the consequences, and develop recommendations to manage the risk. To implement the Delta risk assessment, legislation requires DWR to evaluate the potential impacts on water supplies derived from the Delta based on 50-, 100-, and 200-year projections for each of the following possible impacts: subsidence, earthquakes, floods, climate change & sea level rise, or a combination of the above. The DRMS work will provide the majority of this required information. The report is due to the Legislature no later than January 1, 2008.

Alquist-Priolo Earthquake Fault Zoning Act

The Alquist-Priolo Earthquake Fault Zoning Act intends to minimize the hazards posed to people and property during and immediately following earthquakes. First enacted in 1972 (subsequently amended), the Act prohibits the location of developments and structures for human occupancy across the trace of active faults and regulates construction activities in the corridors of earthquake faults zones. The Act prohibits and restricts construction activities and zoning classifications based upon fault activity and fault definition, providing legal definitions for active, sufficiently active, and well-defined and establishes a process for reviewing construction proposals in the vicinity of earthquake fault zones. Trained geologists conduct site-specific investigations to determine the appropriate zoning classification. Regulations are more stringent for areas of greater hazard potential. The Act identifies Earthquake Special Study Zones. Dutch Slough site is not located in a Special Study Zone.

Seismic Hazards Mapping Act

The Seismic Hazards Mapping Act also intends to provide for a statewide seismic hazard mapping and technical advisory program to assist cities and counties in protecting the public health and safety from the effects of strong ground shaking, liquefaction, landslides, or other ground failure and other seismic hazards caused by earthquakes. Under the Act, the State is responsible for identifying and mapping seismic hazard zones. Cities and counties are required to utilize these hazard maps in issuing building permits, which provides a mechanism to regulate construction and development accordingly in these zones to ensure that building standards provide for safe development. Prior to issuing permits, the Act requires site-specific geotechnical investigations be conducted and development plans incorporate measures to mitigate potential damage in most developments designed for human occupancy within the Zones of Required Investigation.

Local Permitting and Site-Specific Geotechnical Investigations

Construction and development is also subject to local permitting requirements and site-specific geotechnical investigations. This permitting process may differ somewhat by jurisdiction, but generally involves a multi-stage permit review process. Site-specific geotechnical investigations examine geology, soils, land use history, and relevant factors to ensure building standards provide for safe development.

The State Reclamation Board cooperates with federal and State agencies and local governments in establishing, planning, constructing, operating, and maintaining flood control works. Reclamation District 799 is the agency responsible for flood protection and drainage on the Hotchkiss Tract immediately east of the Dutch Slough site. The Reclamation District issues permits for projects that:

- Are within federal flood control project levees and within a Board easement, or
- May have an effect on the flood control functions of project levees, or
- Are within a Board designated floodway, or
- Are within regulated Central Valley streams listed in Table 8.1 in Title 23 of the California Code of Regulations.

3.3.2 Impacts and Mitigation Measures

Significance Criteria

Criteria for determining significant impacts are based upon the CEQA Guidelines (Appendix G) and professional judgment. These guidelines state that the project would have a significant impact on geology, soils, and seismicity if it would:

- Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:

  - Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault

  - Strong seismic ground shaking

  - Seismic-related ground failure, including liquefaction

  - Landslides

- Result in substantial soil erosion or the loss of topsoil
- Be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction or collapse
- Be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property

Additional criteria not explicit to CEQA guidelines but evaluated in this section include:

- Levee failure resulting from erosion
- Levee failure resulting from seepage.

Alternative 1: Minimum Fill

IMPACT 3.3.1-1: EXPOSE PEOPLE OR STRUCTURES TO POTENTIAL SUBSTANTIAL ADVERSE EFFECTS (INCLUDING LEVEE FAILURE) RESULTING FROM A SURFACE RUPTURE OF A KNOWN EARTHQUAKE FAULT

DUTCH SLOUGH RESTORATION PROJECT AND RELATED PROJECTS

Surface ground ruptures are generally confined to a narrow linear zone adjacent to faults. Fault ground rupture is unlikely at Dutch Slough as there are no active faults mapped across the site by the California Geological Survey. The site is not located in a Fault Hazard Zone (Alquist-Priolo Earthquake Special Study Zone). Therefore no impact would occur and no mitigation is required.

OPEN WATER MANAGEMENT OPTIONS

No change in fault rupture impacts would occur with the various open water management options.

SIGNIFICANCE

No Impact; no mitigation required.

IMPACT 3.3.1-2: EXPOSE PEOPLE OR STRUCTURES TO POTENTIAL SUBSTANTIAL ADVERSE EFFECTS (INCLUDING LEVEE FAILURE) RESULTING FROM STRONG SEISMIC GROUND SHAKING

DUTCH SLOUGH RESTORATION PROJECT AND RELATED PROJECTS

As previously stated, strong seismic ground shaking is likely to occur in the Dutch Slough area from a major earthquake in the Bay Area within the next 30 years (USGS 1999). The potential shaking is categorized by the modified Mercalli intensity level VII (defined as Strong). The severity of shaking is dependent upon many factors including the magnitude of the earthquake, distance from epicenter, duration of earthquake, and soil and geology.

Peak ground accelerations (PGA) is a measure of the intensity of ground shaking during an earthquake. The California Geological Society (CGS), USGS, and CALFED Bay-Delta Program have developed probabilistic contour maps of PGA for the region. Several prior technical studies conducted for projects in the immediate vicinity have calculated estimates of PGA (Kleinfelder 2003, 2004, 2006, ENGEO 2004). The Probabilistic Seismic Hazard Assessment for the State of California (Petersen et al. 1996) and subsequent calculations by DCM Engineering (2005) indicate a 10% probability that peak horizontal acceleration from 0.35g to 0.40g ("g" = acceleration of gravity) in 50 years. This corresponds with the CALFED Bay-Delta Program estimates for the Western Delta of 0.35g (1998). A probabilistic analysis conducted by Kleinfelder (2006) for the Jersey Island Road Levee Evaluation for the Cypress Corridor shows similar results with PGA of 0.32, based upon a 475 year return period (10% in 50 years) with an annual probability of exceedence of 0.0021.

The Dutch Slough Restoration Project site is approximately 9 miles from the Greenville Fault. Due to this proximity, the site is identified by the CBC (1998 edition) as located in Seismic Zone 4. The California Probabilistic Seismic Hazard Maps, which identify fault parameters and classifications, classify the Greenville as a Class B fault (Cao et al. 2003). The USGS identifies it as Class A fault (2005). The CBC design guidelines are more stringent for projects located adjacent to a Class A or B fault and require earthquake-resistant design standards based upon a minimum horizontal acceleration of 0.4g. Any structures built as part of the Dutch Slough Project and Related Projects, such as the proposed levee access footbridges and the City Community Park buildings, must meet these standards that are intended to prevent significant structural damage from seismic ground acceleration.

The site consists of unconsolidated soils prone to amplify and prolong strong shaking during earthquakes. Existing levees are constructed on native and imported soils. Levee failure could occur in a major earthquake; this would introduce water from the Bay-Delta onto the site and potentially, depending upon location of failure, into the surrounding vicinity. Repairs and upgrades to existing structures and levees incorporating earthquake-resistant design and construction measures to reduce liquefaction, settlement, and lateral spread would reduce the potential impacts. New levees and structures would be engineered to withstand seismic events to the extent practicable.

Seismic shaking also could damage structures including the City Community Park buildings, infrastructure, and bridges and viewing structures. Conformance to building codes and applicable regulations does not render structures or levees infallible or provide any guarantee that significant structural damage would not result from large magnitude seismic events; however, it does provide reasonable assurance that appropriately designed and constructed structures would be better suited to withstand these events without collapse or loss of life.

OPEN WATER MANAGEMENT OPTIONS

The open-water management option would not influence the likelihood of structural or levee failure due to strong seismic shaking. If the eastern perimeter levee (Jersey Island Road levee) failure occurred, there would be no difference amongst tidal open-water options. Greater potential flood hazard under tidal open water option compared to managed water level because there is greater tidal exchange and potential for inflow. Proper levee design based upon site-specific geotechnical investigations and remediation will reduce potential for impact to less than significant.

MITIGATION MEASURE 3.3.1-2.

Conduct site specific geotechnical investigations to identify and implement appropriate remediation actions (e.g., subgrade densification).

Site-specific geotechnical investigations shall be conducted to determine most appropriate remediation actions for new levees and structures and upgrades or repairs to existing levees and structures. Potential mitigation measures include dynamic deep compaction to densify subgrade soils to reduce impact to less than significant.

SIGNIFICANCE OF IMPACT AFTER MITIGATION

Mitigation Measure 3.3.1-2 would not be infallible against strong seismic activity but would result in levees better suited to withstand seismic events and to the extent practicable and would reduce impacts to less than significant.

IMPACT 3.3.1-3: EXPOSE PEOPLE OR STRUCTURES TO POTENTIAL SUBSTANTIAL ADVERSE EFFECTS (INCLUDING LEVEE FAILURE) RESULTING FROM SEISMIC-RELATED GROUND FAILURE, INCLUDING LIQUEFACTION.

DUTCH SLOUGH RESTORATION PROJECT AND RELATED PROJECTS

As stated above, levees and structures constructed on the property are potentially subject to these hazards resulting from strong seismic events. Design and construction would need to be engineered to withstand seismic activity to the extent practicable and future construction at the site must provide adequate level of protection per USACE and Reclamation District 799 guidelines. All new or relocated historic structures on the restoration site and on the City Community Park must conform to applicable State building codes. Improper design could result in greater susceptibility to damage to structures and levees from liquefaction.

Previous studies including cone penetration tests in the project vicinity (East Cypress Corridor) indicate potential for liquefaction within interbedded sand layers (typically 2 to 5 feet thick) located in the upper 15 to 25 feet of soil (Kleinfelder 2004). Empirical based estimates indicate seismically induced settlement of liquefiable sand layers range from less than 0.5 inch to approximately 3 inches (Kleinfelder 2004). The Geotechnical Consultation of Seepage and Levees at Dutch Slough prepared by Hultgren-Tillis Engineers in August 2005 states that portions of the sand subgrade may be at risk for liquefying in a large earthquake and states that densification treatment (e.g., deep dynamic compaction) may be necessary for FEMA Urban Levee design (Hultgren-Tillis 2005). Liquefaction could potentially damage or destroy project structures, infrastructure, and levees.

MITIGATION MEASURE 3.3.1-3

Conduct site-specific geotechnical investigations to identify and implement appropriate remediation actions (e.g., subgrade densification).

Site-specific geotechnical investigations shall be conducted at Dutch Slough to characterization site conditions. Pre-design and design-level geotechnical field investigations (soil borings, Cone Penetration Tests), laboratory analyses, groundwater analyses would better enable assessing site conditions and constructability of proposed levees and structures on the Dutch Slough Restoration Project site and the City Community Park. These investigations would provide a basis for appropriate Site design for any new and/or improvements to exiting levees and structures on the Dutch Slough Restoration Project site and the City Community Park. Potential methods include treatment such as deep dynamic compaction to densify subgrade soils. These investigations shall supplement recent work presented in Kleinfelder (2006).

SIGNIFICANCE OF IMPACT AFTER MITIGATION

Implementing appropriate design, remediation, and construction measures would engineer levees and structures to withstand seismic events to the extent practicable. These measures would mitigate potential impacts of ground failure to less than significant.

OPEN WATER MANAGEMENT OPTIONS

No change in structural or levee failure impacts would occur with the various open water management options.

IMPACT 3.3.1-4: EXPOSE PEOPLE OR STRUCTURES TO POTENTIAL SUBSTANTIAL ADVERSE EFFECTS RESULTING FROM LANDSLIDES

DUTCH SLOUGH RESTORATION PROJECT AND RELATED PROJECTS

Site topographic surveys indicate relatively flat terrain and geologic maps and aerial photos do not indicate the presence of any landslide hazards. Therefore, there would be no associated impact.

OPEN WATER MANAGEMENT OPTIONS

The open water management option would not affect landslide hazard.

IMPACT 3.3.1-5: SUBSTANTIAL SOIL EROSION OR LOSS OF TOPSOIL

DUTCH SLOUGH RESTORATION PROJECT AND RELATED PROJECTS

Following the proposed breach in the levees, the Dutch Slough Restoration Project site is expected to be depositional. Shallow sub-tidal to intertidal vegetation and emergent marsh species are anticipated to enhance sediment accretion on the site. Erosion from within the site is not anticipated to be problematic. Levee design and embankment buffering and marsh plain vegetation is anticipate to moderate wind and water erosion.

Construction activities and earth moving from both restoration activities and park development have the potential to increase wind and water erosion on a temporary basis. The site is located in a region of high winds and may be subject to wind erosion particularly during construction as soils are excavated, transported and stockpiled on site. Temporary erosion control measures would implemented during construction to minimize erosion in line with construction Best Management Practices (BMPs) and the Stormwater Pollution Prevention Plan (SWPPP).

OPEN WATER MANAGEMENT OPTIONS

The open water management option would not affect topsoil erosion potential. Post-breach the site is anticipated to accrete sediment. Open water management options may influence levee erosion due to differences in potential wind-wave fetch, see discussion under impact 3.3.1.8.

MITIGATION MEASURE 3.3.1-5: IMPLEMENTING EROSION CONTROL BMPS DURING CONSTRUCTION.

Temporary erosion control measures (e.g., silt fences, straw bales, detention basins, check dams, sandbag dikes, geo-fabric, and ground cover) shall be implemented during construction per required BMPs and SWPPP.

SIGNIFICANCE OF IMPACT AFTER MITIGATION

Implementing BMPs and SWPPP during construction will mitigate impacts for erosion and sedimentation to less than significant.

IMPACT 3.3.1-6: LANDSLIDE, LATERAL SPREADING, SUBSIDENCE, LIQUEFACTION, OR COLLAPSE RESULTING FROM CONSTRUCTION ON AN UNSTABLE GEOLOGICAL UNIT OR UNSTABLE SOILS

DUTCH SLOUGH RESTORATION PROJECT AND RELATED PROJECTS

Levees and structures constructed on the Dutch Slough Restoration Project site, as well as the Related Projects sites, are potentially subject to lateral spreading, subsidence, liquefaction hazards resulting from strong seismic events. Landslides are not considered a hazard due to site topography. Improper design and construction could result in liquefaction or subsidence. Design and construction needs to be engineered to withstand earthquakes to the extent practicable and future construction on the restoration site, the community park and levee access pathways must provide adequate level of protection per CBC standards and county, reclamation district, USACE, and State regulations.

Existing levees are constructed of unconsolidated material, but have been in place for decades and to date have not experienced significant landslides, lateral spreading, subsidence, liquefaction or collapse. This does not ensure future stability. Ongoing repair and maintenance of existing levees would be conducted. Fill placement and construction activities along levees and the resulting increasing in loading could increase substrate sheer stress with the potential to result in subsidence and differential settling.

The report, *Geotechnical Consultation Seepage and Levees Dutch Slough Tidal Marsh Restoration* (Hultgren-Tillis Engineers, 2005), indicates that the new proposed levee along the eastern boundary of the Burroughs parcel would be constructed of lean clay. Where necessary, areas of peat would need to be excavated from beneath the proposed levee to expose underlying sand or stiff clay soils. The report recommends incorporation of a wide berm to maintain stability and aid in controlling levee settlement induced by lateral creep. The report also indicates potential for differential settlement at the junction of the new levee and the existing Dutch Slough levee and recommends a core be installed into this segment to minimize risk of piping (internal seepage) due to cracks in the levee resulting from differential settling (Hultgren-Tillis 2005).

OPEN WATER MANAGEMENT OPTIONS

The open water management option would not affect Impact 3.3.1-6.

MITIGATION MEASURE 3.3.1-6

Pre-design and design-level geotechnical field investigations (soil borings, Cone Penetration Tests) and laboratory analyses shall be conducted to determine soil characteristic and strength to enable an assessment of site conditions and constructability. Field investigations and laboratory results shall be included in geotechnical reports and form the basis for appropriate site design. Potential methods to address liquefaction include deep dynamic compaction to densify subgrade soils. A geotechnical engineer shall monitor and provide oversight of field construction activities including excavation, fill placement, and materials removed from and deposited at the site.

As recommended in the Hultgren-Tillis (2005) Levee and Seepage report, the new proposed levee along the eastern boundary of the Burroughs parcel shall be constructed of lean clay. Where necessary, areas of peat would need to be excavated from beneath the proposed levee to expose underlying sand or stiff clay soils. Levee design shall include a wide berm to maintain stability and aid in controlling levee settlement induced by lateral creep. To minimize potential for differential settlement and risk of internal piping (seepage) a core should installed into levees segments as needed.

If Marsh Creek is relocated, site-specific soils investigations shall be conducted at the selected diversion point, and any improvements identified implemented as necessary.

SIGNIFICANCE OF IMPACT AFTER MITIGATION.

Implementing appropriate design, remediation, and construction measures would mitigate impact to less than significant.

IMPACT 3.3.1-7: RISK TO LIFE OR PROPERTY RESULTING FROM CONSTRUCTION OF STRUCTURES ON EXPANSIVE SOILS

Soil surveys indicate significant portions of the Dutch Slough Restoration Project and Related Project sites include Sacramento and Marcus clay soils characterized as expansive with high potential to shrink-swell (SCS 1977). Portions of the City Community Park also overlie expansive clay soils that are prone to shrink-swell with moisture. Volume changes may occur resulting from changes in water table levels and placement of fill material. These changes can damage foundations, roadways, pipes, and other infrastructure. Potential significant impacts can be mitigated to less than significant or avoided by implementing the mitigation measures identified below.

OPEN WATER MANAGEMENT OPTIONS

The choice of open water management option would not affect this impact.

MITIGATION MEASURE 3.3.1-7: REMOVE AND/OR REMEDIATE UNSTABLE OR EXPANSIVE SOILS

Design level geotechnical investigations shall be conducted to assess presence of expansive soils and identify most appropriate remediation measures for the restoration site and the proposed community park. In the event that unstable or expansive geologic units or soils are encountered during the geotechnical investigations and are deemed unsuitable for construction, remedial measures shall be implemented, including removing soils and backfill with engineered fill or imported offsite material, re-grading with non-expansive soils, soil lime treatment, or otherwise treating soils to decrease shrink/swell potential and otherwise satisfy the required specifications for compaction and shear strength. All structures shall adhere to building codes; this would reduce risk to life or property and reduce impacts to less than significant levels.

SIGNIFICANCE OF IMPACT AFTER MITIGATION

Implementation of the mitigation measure identified above would reduce these impacts to less than significant.

IMPACT 3.3.1-8: LEVEE FAILURE RESULTING FROM EROSION

DUTCH SLOUGH RESTORATION PROJECT AND RELATED PROJECTS

Wind and water are principal causes of erosion that may result in weathering and transport of soils from the site. The site is currently subject to wind erosion and outboard levees subject to water erosion from channel flow and tidal action. Alternative 1 includes breaching the existing levees which would result in an increase in the tidal prism (water volume and velocity) entering and exiting the parcels. Breaching the levees has the potential to increase erosion adjacent to the breaches and along interior levees by subjecting levees to daily fluctuations in water levels, daily wetting/drying cycles, and wind-driven erosion. Breaching existing perimeter levees would increase the potential for greater wind-wave fetch and relatively larger wave run-up for all perimeter levees adjacent to open water and marsh areas. Wind-wave action may scour, erode and weaken levees. Some erosion may be acceptable within the restoration design objectives. However, unintended breaches along sloughs would increase tidal exchange and potentially result in channel erosion and increase exchange to the extent that other portions of levees are subject to increased likelihood of erosion and potential failure. Unintended breaches along Dutch Slough and the accompanying increase in localized flow velocities could potentially increase erosion scour of the Jersey Island levees.

DWR, the City of Oakley, RD799, and developers of adjacent nearby parcels are evaluating the feasibility of cost-sharing for the construction of a levee along jersey Island Road that will provide 300-year flood protection, as well as protect the areas from possible seepage associated with the Dutch Slough Restoration Project. This increased protection would be far greater than the less than 100-year flood protection provided by the existing levees.

OPEN WATER MANAGEMENT OPTIONS

Potential for levee erosion differs between open water management options because of differences in the size and depth of open water areas and resulting differences in wind-wave fetch. The deep-water tidal option has relatively greater potential for eroding levees than the other two tidal options. Of the non-tidal managed alternatives, the pond option has greater potential for erosion than the subsidence reversal due to greater water depths and thus increased wind-wave fetch potential. Regardless of option, the impact is considered less than significant because the perimeter levee designs are to include levee buffering, flat slopes, and vegetation cover that collectively act to dissipate wave energy and minimize erosion potential.

MITIGATION MEASURE 3.3.1-8. LEVEE MAINTENANCE

3.3.1-8.1 Levee design and maintenance. Levees shall include vegetation cover and biotechnical and/or physical buffering and feature gently graded slopes. Levees planted with marsh and riparian vegetation in and feature flatter slopes provide a wave-damping wetland bench will dissipate wave energy and minimize erosion as well as support habitat objectives. Periodic levee inspections and maintenance shall be specified as part of the project design. Anticipated levee maintenance activities include levee inspections and patrolling, grading, engineering, vegetation and rodent control, debris removal, drainage cleaning, seepage control, underwater surveys, and slope protection.

3.3.1-8.2 Repair unintended levee breaches. To prevent channel erosion and potential damage to the levee systems, unintended levee breaches at Dutch Slough that are not consistent with the restoration option shall be repaired by the project sponsors.

3.3.1-8.3 Maintain levee along Dutch Slough. Levees along Dutch Slough shall be maintained to prevent increase in wind-wave fetch that could lead to greater erosion and scour of Jersey Island levees.

3.3.1-8.4 Jersey Island Road levee shall account for increased wave run up. Due to greater fetch and potential wave run-up due to greater surface water area post-breach, the design height of the new Jersey Island Road levee shall be adequate to prevent account for increased water heights due to wave run-up.

SIGNIFICANCE OF IMPACT AFTER MITIGATION.

Less than significant

IMPACT 3.3.1-9: LEVEE FAILURE RESULTING FROM SEEPAGE

DUTCH SLOUGH RESTORATION PROJECT AND RELATED PROJECTS

Seepage is recognized as a key mechanism leading to levee failure (DWR 2005). Through-seepage occurs in levees containing portions of relatively porous material, that when subjected to prolonged inundation (e.g., high water flood events) provide flow pathways through levees. Under-seepage has the potential to occur in levees underlain by porous soils, such as sand, that allow flow beneath a levee to the surface on the landward side. If left uncontained, this flow may result in pressure on the landward side of levees causing ruptures in the surface soils resulting in visible boils. These conduits of flow result in levee slumping and eventual overtopping and failure.

Levee failure is principally a concern along the perimeter of the site due to potential flooding damage to infrastructure in surrounding parcels. The PWA Feasibility Report states a new levee along the eastern boundary of the project will provide "in-kind" replacement of the existing levee currently around the Burroughs parcel along Dutch Slough and Little Dutch Slough (PWA 2006). In-kind replacement will not increase existing levee of flood protection, which offers less than 100-year flood protection.

Hultgren-Tillis Engineers (2005) developed a conceptual criterion for the in-kind levee replacement, an upgrade from in-kind to FEMA urban levee, and a FEMA urban levee. The FEMA urban levee offers increased flood protection. The Feasibility Study states upgrading from the in-kind levee replacement is not the responsibility of the Dutch Slough Restoration Project, though the potential for upgrade may exist through a cost-sharing partnership with responsible parties. The details of the cost-sharing partnership and the levee design specifications of the Jersey Island Road levee are currently under negotiation between the Department of Water Resources, Reclamation District 799, and the residential developer building on the Hotchkiss Tract (personal communication with Tom Hall, July 27, 2006).

The Hultgren-Tillis report indicates that the new proposed levee along the eastern boundary of the Burroughs parcel should be constructed of lean clay. The report also indicates potential for differential settlement at the junction of the new levee and the existing Dutch Slough levee and recommends a core be installed into this segment to minimize risk of piping (internal seepage) due to cracks in the levee resulting from differential settling (Hultgren-Tillis 2005). The report indicates that were the new levee intended to be a FEMA Urban Levee, the inclusion of an internal drain as a seepage control measure would reduce the risk in through-seepage (piping). The report recommends the inclusion of seepage ditches on the outside toes of new and existing levees around Dutch Slough that would act to pull the water level down beneath the levee toe to reduce the risk of seepage from the face of the levee. The Jersey Island Levee Road Levee evaluation by Kleinfelder proposes use of a pervious 25-foot blanket drain below the toe of the levee in conjunction with an internal perforated drainage pipe to incept potential internal seepage (Kleinfelder 2006). Inclusion of a chimney drain at the interior end of the blanket drain would provide an additional safety factor against seepage potentially by-passing the blanket drain due to soil layering or stratification (Kleinfelder 2006).

DWR, the City of Oakley, RD799, and developers of adjacent nearby parcels are evaluating the feasibility of cost-sharing for the construction of a levee along jersey Island Road that will provide 300-year flood protection, as well as protect the areas from possible seepage associated with the Dutch Slough Restoration Project. This increased protection would be far greater than the less than 100-year flood protection provided by the existing levees.

The potential impact of levee failure resulting from seepage is significant; however the proposed levee design would reduce this impact to less than significant.

Open Water Management Options

There may be a slight difference in levee seepage potential between open water management options insofar as the options result in different water heights within the managed area and thus different gradients between surface water on either side of levees adjacent to the open water management areas. These differences are not expected to be great enough to affect the significance level of this impact after mitigation.

Mitigation 3.3.1-9 Appropriate levee design, construction, monitoring and maintenance

The project design shall comply with HTA and Kleinfelder design criteria and geotechnical investigations and shall incorporate consultation with the USACE, Reclamation District 799 and Reclamation District 830, and appropriate design and construction. The seepage potential of the selected Open Water Management option shall be evaluated as part of geotechnical investigations and consultations.

Significance of impact after mitigation

The mitigation identified above would reduce impacts to less than significant.

Alternative 2: Moderate Fill Alternative

Impact 3.3.2-1: Expose people or structures to potential substantial adverse effects (including levee failure) resulting from a surface rupture of a known earthquake fault

Impacts and mitigations are the same as Alternative 1 (for all options).

Impact 3.3.2-2: Expose people or structures to potential substantial adverse effects (including levee failure) resulting from strong seismic ground shaking

Impacts and mitigations are the same as Alternative 1 (for all options).

Impact 3.3.2-3: Expose people or structures to potential substantial adverse effects (including levee failure) resulting from seismic-related ground failure, including liquefaction.

Impacts and mitigations are the same as Alternative 1 (for all options).

Impact 3.3.2-4: Expose people or structures to potential substantial adverse effects resulting from landslides

Impacts and mitigations are the same as Alternative 1 (for all options).

Impact 3.3.2-5: Substantial soil erosion or loss of topsoil

Impacts and mitigations are the same as Alternative 1 for the Dutch Slough Restoration Project and Related Projects and Open Water Management options.

Marsh Creek Delta Relocation Options

Relocating Marsh Creek from its current channel into the Emerson Parcel has the potential to introduce scouring flows during major storm events into the restoration site. These flows could cause erosion of existing soils or of fill soils placed for wetland restoration purposes. Scoured soils may be relocated elsewhere within the Emerson Parcel or transported into Dutch Slough. The extent of potential scour and transport depends on which Marsh Creek Delta Relocation Option (see Figure 2-13) is considered. There is a greater potential to occur the further south the diversion into Emerson Parcel is situated. This issue is described further, and mitigation identified as a component of the Marsh Creek Delta Relocation hydrologic evaluation described in Chapter 3.1.

Impact 3.3.2-6: Landslide, lateral spreading, subsidence, liquefaction, or collapse resulting from construction on an unstable geological unit or unstable soils

Impacts and mitigations are the same as Alternative 1 (for all options).

Impact 3.3.2-7: Risk to life or property resulting from construction of structures on expansive soils

Impacts and mitigations are the same as Alternative 1 (for all options).

Impact 3.3.2-8: Levee failure resulting from erosion

Impacts and mitigations are the same as Alternative 1 (for all options).

Impact 3.3.2-9: Levee failure resulting from seepage

Impacts and mitigations are the same as Alternative 1 (for all options).

Alternative 3: Maximum Fill

Impact 3.3.3-1: Expose people or structures to potential substantial adverse effects (including levee failure) resulting from a surface rupture of a known earthquake fault

Impacts and mitigations are the same as Alternatives 1 and 2 (for all options).

Impact 3.3.3-2: Expose people or structures to potential substantial adverse effects (including levee failure) resulting from strong seismic ground shaking

Dutch Slough Restoration Project and Related Projects

As discussed for Alternative 1, strong seismic ground shaking is likely to occur at the Dutch Slough site in a major earthquake. The potential for structural and levee damage is previously discussed under Alternative 1.

The potential flood hazard is comparatively less for Alternative 3 than for Alternatives 1 and 2 because the Alternative 3 design has less open water on the Gilbert and Burroughs parcel. The design indicates channels present on the Burroughs parcel, but no open water along the eastern perimeter

(Jones Island Road levee), which reduces the threat of flooding along this boundary due to levee failure.

Incorporating earthquake-resistant levee design and construction measures to reduce liquefaction, settlement, and lateral spread may reduce the potential impacts. Conformance to building codes and applicable regulations would not render structures or levees infallible or provide any guarantee that significant structural damage will not result from large magnitude seismic events; however, it would provide reasonable assurance that appropriately designed and constructed structures would be better suited to withstand these events without collapse or loss of life.

MITIGATION MEASURE 3.3.3-2

Conduct site-specific geotechnical investigations to identify and implement appropriate remediation actions (e.g., subgrade densification).

Mitigation is the same as Alternatives 1 and 2.

SIGNIFICANCE OF IMPACT AFTER MITIGATION

Mitigation Measure 3.3.3-2 is not infallible against strong seismic activity but would result in levees better suited to withstand seismic events to the extent practicable and therefore reduce impacts to less than significant.

OPEN WATER MANAGEMENT OPTIONS

The open water management option would not influence the likelihood of structural or levee failure due to strong seismic shaking. The potential impacts do not differ amongst tidal open water options. Impacts would be mitigated to less than significant with Mitigation Measure 3.3.3-2.

MARSH CREEK DELTA RELOCATION

Marsh Creek Delta Relocation options would not influence the likelihood of structural or levee failure due to strong seismic shaking or potential impacts.

IMPACT 3.3.3-3: EXPOSE PEOPLE OR STRUCTURES TO POTENTIAL SUBSTANTIAL ADVERSE EFFECTS (INCLUDING LEVEE FAILURE) RESULTING FROM SEISMIC-RELATED GROUND FAILURE, INCLUDING LIQUEFACTION.

As stated previously, levees and structures constructed on the property are potentially subject to these hazards resulting from strong seismic events. Design and construction needs to be engineered to withstand seismic activity to the extent practicable and per local, state and federal guidelines.

The potential flood hazard is comparatively less for Alternative 3 than for Alternatives 1 and 2 because the Alternative 3 design has less open water on the Gilbert and Burroughs parcel. The design indicates channels present on the Burroughs parcel, but no open water along the eastern perimeter (Jersey Island Road levee), which would reduce the threat of flooding along this boundary due to levee failure.

OPEN WATER MANAGEMENT OPTIONS

The open water management option would not influence the likelihood of levee failure due to seismic-related ground failure or effect potential impacts.

MARSH CREEK DELTA RELOCATION OPTIONS

Marsh Creek Delta Relocation would not affect the likelihood of levee failure due to seismic-related ground failure or affect potential impacts.

MITIGATION MEASURE 3.3.3-3.

Conduct site-specific geotechnical investigations to identify and implement appropriate remediation actions (e.g., subgrade densification).

Mitigation is the same as for Alternatives 1 and 2.

SIGNIFICANCE OF IMPACT AFTER MITIGATION

Less than significant

IMPACT 3.3.3-4: EXPOSE PEOPLE OR STRUCTURES TO POTENTIAL SUBSTANTIAL ADVERSE EFFECTS RESULTING FROM LANDSLIDES

Impacts and mitigations are the same as Alternatives 1 and 2.

IMPACT 3.3.3-5: SUBSTANTIAL SOIL EROSION OR LOSS OF TOPSOIL

Impacts and mitigations are the same as Alternatives 1 and 2.

IMPACT 3.3.3-6: LANDSLIDE, LATERAL SPREADING, SUBSIDENCE, LIQUEFACTION, OR COLLAPSE RESULTING FROM CONSTRUCTION ON AN UNSTABLE GEOLOGICAL UNIT OR UNSTABLE SOILS

Impacts and mitigations are the same as Alternatives 1 and 2.

IMPACT 3.3.3-7: RISK TO LIFE OR PROPERTY RESULTING FROM CONSTRUCTION OF STRUCTURES ON EXPANSIVE SOILS

Impacts and mitigations are the same as Alternatives 1 and 2.

IMPACT 3.3.3-8: LEVEE FAILURE RESULTING FROM EROSION

DUTCH SLOUGH RESTORATION PROJECT AND RELATED PROJECTS

As with Alternatives 1 and 2, there would be the potential for outboard levee erosion on all parcels and on levees of open water area of Emerson parcels. However, due to lack of open water on the Gilbert and Burroughs parcels, the likelihood of erosion and scour on inboard levees is comparatively less for Alternative 3. Potential flood hazard along Jersey Island Road levee is least for Alternative 3 since it does not feature open water in Burroughs parcel.

OPEN WATER MANAGEMENT OPTIONS

Potential for levee erosion differs between open water management options because of differences in the size and depth of open water areas and resulting differences in wind-wave fetch. The deep-water tidal option has relatively greater potential for eroding levees than the other two tidal options. Of the non-tidal managed alternatives, the pond option has greater potential for erosion than the subsidence reversal due to likelihood for greater potential for wind-wave fetch. Regardless of option, the impact is considered less than significant because levee design is to include levee buffering, flat slopes, and vegetation cover which collectively act to dissipate wave energy and minimize erosion potential.

MARSH CREEK DELTA RELOCATION OPTIONS

Marsh Creek Delta Relocation options do not differ in their potential to result in levee erosion.

MITIGATION MEASURE 3.3.3-8 LEVEE MAINTENANCE

Mitigation is the same as for Alternatives 1 and 2.

SIGNIFICANCE OF IMPACT AFTER MITIGATION

Less than significant

IMPACT 3.3.3-9: LEVEE FAILURE RESULTING FROM SEEPAGE

DUTCH SLOUGH RESTORATION PROJECT AND RELATED PROJECTS

As discussed in Alternative 1, through-seepage and under-seepage are mechanisms leading to levee failure. Levee failure is principally a concern along the perimeter of the site due to potential flooding damage to infrastructure in surrounding parcels.

The lack of open water on the Gilbert and Burroughs parcels would reduce the likelihood of seepage under Alternative 3 compared to Alternatives 1 and 2.

OPEN WATER MANAGEMENT OPTIONS

Potential for levee failure resulting from seepage does not differ amongst open water management options.

MARSH CREEK DELTA RELOCATION OPTIONS

Potential for levee failure resulting from seepage does not differ amongst marsh creek relocation options.

MITIGATION 3.3.3-9 APPROPRIATE LEVEE DESIGN, CONSTRUCTION, MONITORING AND MAINTENANCE.

Mitigations are the same as Alternatives 1 and 2.

SIGNIFICANCE OF IMPACT AFTER MITIGATION.

Less than significant

Alternative 4: No Project

IMPACT 3.3.4-1: EXPOSE PEOPLE OR STRUCTURES TO POTENTIAL SUBSTANTIAL ADVERSE EFFECTS (INCLUDING LEVEE FAILURE) RESULTING FROM A SURFACE RUPTURE OF A KNOWN EARTHQUAKE FAULT

Surface ground ruptures are generally confined to a narrow linear zone adjacent to faults. Fault ground rupture is unlikely at Dutch Slough as there are no active faults mapped across the site by the California Geological Survey. As with Alternatives 1-3, the site is not located in a Fault Hazard Zone (Alquist-Priolo Earthquake Special Study Zone). Therefore, this impact is considered less than significant and no mitigation is required.

IMPACT 3.3.4-2: EXPOSE PEOPLE OR STRUCTURES TO POTENTIAL SUBSTANTIAL ADVERSE EFFECTS (INCLUDING LEVEE FAILURE) RESULTING FROM STRONG SEISMIC GROUND SHAKING

As discussed for Alternative 1, strong seismic ground shaking is likely to occur at the Dutch Slough site in a major earthquake. Existing levees and structures are likely to be subject to potential damage. Aerial photos indicate minimal presence of structures within the Dutch Slough Restoration Project boundaries (PWA 2006). Levee failure would introduce water from the Bay-Delta onto the site and potentially, depending upon location of failure, into the surrounding vicinity. Under the No Project Alternative option, existing levees around the Dutch Slough parcels will not be rebuilt but will be maintained. DWR, the City of Oakley, RD799, and developers of adjacent nearby parcels are evaluating the feasibility of cost-sharing for the construction of a levee along jersey Island Road that will provide 300-year flood protection, as well as protect the areas from possible seepage associated with the Dutch Slough Restoration Project. This increased protection would be far greater than the less than 100-year flood protection provided by the existing levees.

. Under this No-Project Alternative, this new levee would be the sole responsibility of the Hotchkiss Tract development. Impacts of flooding adjacent parcels or the Contra Costa canal to the south are significant

MITIGATION 3.3.4-2: LEVEE MONITORING AND MAINTENANCE

Ongoing repair and maintenance of existing levees shall be conducted by RD 799 and RD 2137.

SIGNIFICANCE OF IMPACT AFTER MITIGATION

Less than significant

IMPACT 3.3.4-3: EXPOSE PEOPLE OR STRUCTURES TO POTENTIAL SUBSTANTIAL ADVERSE EFFECTS (INCLUDING LEVEE FAILURE) RESULTING FROM SEISMIC-RELATED GROUND FAILURE, INCLUDING LIQUEFACTION.

As stated above, levees and structures constructed on the property are potentially subject to these hazards resulting from strong seismic events. Levee failure is a significant impact as it would introduce water from the Bay-Delta onto the site and potentially, depending upon location of failure, onto the adjacent parcels and the Contra Costa Canal. This impact is considered significant.

MITIGATION 3.3.4-3: LEVEE MONITORING AND MAINTENANCE

As stated, the existing levees are constructed of unconsolidated material, but have been in place for decades and to date have not experienced significant landslides, lateral spreading, subsidence, liquefaction, seepage or collapse. This does not ensure future stability.

Potential mitigations are identified in Alternatives 1 and 2. Ongoing levee maintenance is required.

SIGNIFICANCE OF IMPACT AFTER MITIGATION.

Less than significant

IMPACT 3.3.4-4: EXPOSE PEOPLE OR STRUCTURES TO POTENTIAL SUBSTANTIAL ADVERSE EFFECTS RESULTING FROM LANDSLIDES

Site topographic surveys indicate relatively flat terrain and geologic maps and aerial photos do not indicate the presence of any landslide hazards. Potential for levee sloughing/sliding is mitigated through proper levee design, construction and maintenance as previously identified in Alternatives 1 and 2. There is no associated impact.

IMPACT 3.3.4-5: SUBSTANTIAL SOIL EROSION OR LOSS OF TOPSOIL

The project site is currently subject to wind erosion and wind-wave erosion along outboard levees. Currently, Reclamation Districts 799 and 2137 maintain the Dutch Slough levees and will continue to maintain them. The site is located in an area of high winds and is subject to potential wind erosion. The predominant land use is agriculture and grazing. Under this land management regime, the potential for wind erosion varies with seasonality, crop cover, mowing, disking, and related grazing density and rotation activities. The impacts from these ongoing actions are less than significant. No mitigation is required.

IMPACT 3.3.4-6: RISK TO LIFE OR PROPERTY RESULTING FROM CONSTRUCTION OF STRUCTURES ON EXPANSIVE SOILS

Soil surveys indicate significant portions of the Dutch Slough site include soils with high potential to shrink-swell (SCS 1977). As proposed, the No Project alternative proposes to maintain the Site as open space under current agricultural land uses in which case the potential impacts are less than significant. However, pending extent and nature of potential future structural development the mitigation measures outlined in Alternative 1 are available to reduce potential impacts to less than significant.

IMPACT 3.3.4-7: LEVEE FAILURE RESULTING FROM EROSION

The site is currently subject to wind erosion and outboard levees are subject to water erosion from channel flow and tidal action. Wind-wave action may scour and erode and weaken levees at the Dutch Slough Restoration Project site. As discussed, levee failure poses flood hazard potential for adjacent properties. Potential impacts from levee erosion are significant. As currently done, routine inspection, maintenance, and repair would continue to be necessary.

Development proposed on the Hotchkiss Tract to the east of Jersey Island Road would be subject to effects of levee failure on the Burroughs Tract unless that development provides an independently constructed flood control levee. Under this no-action alternative, the negotiations currently underway between DWR, the City of Oakley, and developers of adjacent/nearby parcels to determine the feasibility of mutually contributing towards the construction of a levee along Jersey Island

Road that would provide 300-year flood protection, as well as protect adjacent areas from possible seepage associated with the restoration project, are not applicable.

Under the No Project alternative, Bethel Island and Jersey Island levees would continue to be subject to wind-wave scour and erosion. These levees would continue to require routine inspection, maintenance, and repair. The No-Project alternative would not alter existing conditions and would not improve the Bethel Island and Jersey Island levees, thus would not increase or decrease their likelihood of failure resulting from erosion.

MITIGATION MEASURE 3.3.4-7: LEVEE MONITORING AND MAINTENANCE

Ongoing levee maintenance activities such as levee inspections and patrolling, grading, engineering, vegetation and rodent control, debris removal, drainage cleaning, seepage control, underwater surveys, and slope protection can reduce the likelihood of failure. These activities will continue to be the responsibility of Reclamation District 799 and 2137.

SIGNIFICANCE OF IMPACT AFTER MITIGATION

Less than significant

IMPACT 3.3.4-8: LEVEE FAILURE RESULTING FROM SEEPAGE

As previously discussed, seepage poses a threat to the stability of levees and has the potential to result in failure. The existing levees are constructed of unconsolidated material, but have been in place for decades and to date have not experienced significant landslides, lateral spreading, subsidence, liquefaction, seepage or collapse. This does not ensure future stability. Ongoing repair and maintenance of existing levees is necessary, as levees throughout the Delta are subject failure from seepage. Levee failure poses flood hazard potential for adjacent properties.

MITIGATION 3.3.4-8 LEVEE MONITORING AND MAINTENANCE

Ongoing levee maintenance activities such as levee inspections and patrolling, grading, engineering, vegetation and rodent control, debris removal, drainage cleaning, seepage control, underwater surveys, and slope protection can reduce the likelihood of failure. However, given the age of the levees, the lack of specificity regarding material used to construct them, it is likely the levees do not provide the level of protection new, properly designed and constructed levees provide.

SIGNIFICANCE OF IMPACT AFTER MITIGATION

Less than significant

Cumulative Impacts

The Dutch Slough Restoration site is located in an area that is undergoing rapid development, with multiple residential developments in the area proposed, approved, or already under construction. Implementing the Dutch Slough Restoration would not result in cumulative impacts upon geology and soils as proper design and construction of levees and structures and adherence to building code regulations would reduce impacts to less than significant. These mitigated impacts are not additive in nature and do not produce cumulative impacts. Impacts of soil erosion are minor or temporary and can be effectively mitigated by using Best Management Practices at time of construction, as previously discussed. The potential flood hazard due to levee failure impacting residential and commercial developments located on subsided lands in historical floodplain is a concern throughout the Delta. The increase in residential development around Dutch Slough increases overall flood hazard potential in the event of levee failure. DWR, the City of Oakley, RD799, and developers of adjacent nearby parcels are evaluating the feasibility of cost-sharing for the construction of a levee along jersey Island Road that would provide 300-year flood protection, as well as protect the areas from possible seepage associated with the Dutch Slough Restoration Project. This increased protection would be far greater than the less than 100-year flood protection provided by the existing levees.

The existing levees on the Emerson and Gilbert parcels would continue to be maintained by the Reclamation Districts and therefore implementation of the Dutch Slough restoration would not increase likelihood of levee failure and would not add to cumulative impacts.

An additional factor that requires consideration for prudent planning and consideration of restoration outcomes are projected increases in sea level rise as this relates to levee design height and flood hazard potential. Sea level rise projections are discussed in Section 3..1, Hydrology. A variety of estimates quantify the range of potential sea level rise, report observed trends and offer predictions of global warming and the potential impacts (IPCC 2001, CCCC 2006). The Intergovernmental Panel on Climate Change reports that over the last 100 years the eustatic (globally averaged) sea level rise was 1 – 2 mm/year (0.3 – 0.6 ft/century). The IPCC projects rates of sea level rise to increase over the next century, with projected increases ranging from 0.4 - 2.9 ft by 2100 (IPCC 2001). More recent estimates by the California Climate Change Center[1] report sea level rise in California over the past century to be approximately 7 inches (0.6 ft), and projects increases of 22 to 35 inches (1.8 to 2.9 ft) by 2100 (CCCC 2006).

The CALFED Independent Science Board (ISB) has evaluated the effects of sea level rise with respect to the Delta and concluded that current projections of sea level rise by the IPCC are likely very conservative as the models used to develop these projections under-estimate recent measured sea level rise (Jeffery Mount, ISB, memo to Mike Healy, CALFED, September 4, 2007). The ISB found that extrapolation from empirical models of sea level rise yields significantly higher estimates of sea level over the next few decades than the IPCC projections. The ISB suggests that the empirical projections are probably a better basis for short to mid term planning. The ISB further noted that neither approach to estimating future sea levels takes account of melting of ice in Greenland and Antarctica, which recent studies suggest is accelerating.

Based on their analysis, the ISB suggests that a mid range rise in sea level this century is likely to be at least 70-100 cm (27-39 inches), significantly greater (~200 cm/78 inches) if ice cap melting accelerates. While the absolute rise is alarming enough, even more alarming is the fact that only a few cm of sea level rise will greatly increase the frequency, intensity and duration of extreme water levels. It is these events that pose the greatest risk to Delta levees, infrastructure and private property.

The projected increase in sea-level will alter historical storm frequency predictions by decreasing reoccurrence intervals and increasing vulnerability of coastal regions to flooding (CCCC 2006). To provide context with a generalized scenario, an increase in sea-level of 1 foot means that storm-surge induced flood events that formerly occurred as 100-year events would more likely occur at a 10-year interval (CCCC 2006). Local sea level rise depends upon a number of physical factors including local land vertical movement (uplift/subsidence) and hydrodynamic responses. In the ab-

[1] The California Climate Change Center report is a multi-institution collaboration among the California Air Resources Board, California Department of Water Resources, California Energy Commission, CalEPA, and the Union of Concerned Scientists.

sence of site-specific data, levee design height should account for predicted increases in sea level rise to the extent practicable.

Table 3.3-2: Summary of Geological and Soils Impacts for Dutch Slough and Related Restoration Projects

	Impact No.	Impact Description	Dutch Slough Restoration Project	Related Projects	
				Ironhouse Project	City Community Park Project
Alternatives 1, 2, and 3	3.3.1-1; 3.3.2-1; 3.3.3-1	Expose people or structures to potential substantial adverse effects (including levee failure) resulting from a surface rupture of a known earthquake fault			
	3.3.1-2; 3.3.2-2; 3.3.3-2	Expose people or structures to potential substantial adverse effects (including levee failure) resulting from strong seismic ground shaking	X	X	X
	3.3.1-3 3.3.2-3 3.3.3-3	Expose people or structures to potential substantial adverse effects (including levee failure) resulting from ground failure, including liquefaction	X	X	X
	3.3.1-4 3.3.2-4 3.3.3-4	Expose people or structures to potential substantial adverse effects resulting from landslides			
	3.3.1-5 3.3.2-5 3.3.3-5	Substantial soil erosion or loss of topsoil	X	X	X
	3.3.1-6 3.3.2-6 3.3.3-6	Landslide, lateral spreading, subsidence, liquefaction, or collapse resulting from construction on an unstable geological unit or unstable soils	X	X	X
	3.3.1-7 3.3.2-7 3.3.3-7	Risk to life or property resulting from construction of structures on expansive soils	X	X	X
	3.3.1-8 3.3.2-8 3.3.3-8	Levee failure resulting from erosion	X	X	X
	3.3.1-9 3.3.2-9 3.3.3-9	Levee failure resulting from seepage	X	X	X

Table 3.3-3: Summary of Geological and Soils Mitigation Applicability for Dutch Slough and Related Restoration Projects

	Mitigation	Dutch Slough Resto-ration Project	Related Projects	
			Ironhouse Project	City Commu-nity Park Project
Alternative 1, 2, 3	Mitigation Measure 3.3.1-2 Conduct site specific geotechnical investigations	X	X	
	Mitigation Measure 3.3.1-3 Site specific geotechnical investigations to characterization conditions	X	X	
	Mitigation Measure 3.3.1-5 Temporary construction BMPs will be implemented during construction to mini-mize erosion.	X	X	X
	Mitigation Measure 3.3.1-6 Implement appropriate remediation measures per results of site-specific geotech-nical field investigations.	X	X	X
	Mitigation Measure 3.3.1-7 Remove and/or remediate unstable or expansive soils.	X	X	
	Mitigation Measure 3.3.1-8.1 Levee design and maintenance.	X	X	X
	Mitigation Measure 3.3.1.-8.2 Repair unintended levee breaches.	X	X	X
	Mitigation Measure 3.3.1-.8.3 Maintain levee along Dutch Slough.	X		
	Mitigation Measure 3.3.1-8.4 Design height of new Jersey Island Road levee to account for increase in fetch resulting wave run-up potential.	X		
	Mitigation 3.3.1-9 Appropriate levee design, construction, monitoring and maintenance.	X		